

CHAPTER 16

Design Guidelines for Wastewater Treatment Systems Using Spray Irrigation

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SPRAY IRRIGATION LAND TREATMENT SYSTEMS

16.1 General

16.1.1 General

This chapter provides guidelines and criteria for the design of surface spray irrigation land treatment systems.

The wastewater loading rate is limited by the maximum amount of a particular wastewater constituent that can be applied to a specific site. For wastewater from municipalities, the limiting design factor is usually either the hydraulic capacity of the soil or the nitrogen content of the wastewater. For industrial wastewater, the limiting design factor may be the hydraulic capacity of the soil, nitrogen or any other wastewater constituent such as metals, organics, etc.

16.1.2 Applicability

Spray irrigation wastewater treatment systems must be designed and operated so that there is no direct discharge to surface waters. Treatment consists of evaporation directly to the atmosphere, by transpiration to the atmosphere via vegetation uptake and by percolation to groundwater. A State of Tennessee Operation Permit (SOP) is required for operation of spray irrigation land treatment systems.

16.1.3 Location

The spray irrigation treatment site should be relatively isolated, easily accessible and not susceptible to flooding. The site can be developed on agricultural land and/or forests or can include parks, golf courses, etc. Site location shall take into account dwellings, roads, streams, etc. A site evaluation by the Division of Water Pollution will be required before review of the Engineering Report and/or application for an SOP.

16.1.4 Topography

Maximum grades for wastewater spray fields should be limited to 8% for row crops, 15% for forage crops and 30% for forests. The maximum grade for any surface spreading system should be 10%. Ideally, a site should have no more than a 2% to 3% slope. The greater the slope the greater potential for lateral subsurface drainage, ponding and extended saturation of the soil. Depressions, sink holes, etc., are to be avoided.

16.1.5 Soils

The infiltrative capacity of soil is a critical factor to be considered when designing any type of spray irrigation system.

If the profile of a particular soil considered for spray irrigation extended to a significant depth without a restrictive horizon (most limiting layer), the ability to load that soil per unit area would be relatively high. On the other extreme, if a soil being considered for spray irrigation has a shallow restrictive horizon, the ability to load that soil would be lower relative to the deeper soil. Depth to restrictive horizon, soil permeability and slope of the restrictive horizon are factors that control the amount and rate at which ground water can exit an area. If the amount of treated effluent applied to an area, in combination with rainfall over the area and groundwater moving into the area, exceed the soil profile's ability to transmit the water away from the application area, surface runoff of wastewater effluent will likely occur.

Evaluation of a soil area's suitability for spray irrigation should take into consideration limiting aspects of the soil profile. Sites with shallow restrictive horizons overlain by low permeability soils represent one of the more limited scenarios for spray irrigation and the application rate and/or application area should be suitably modified.

Also critical when designing systems in soils with shallow restrictive horizons are the presence and location of hydrologic boundaries such as drainage ways and waterways. These hydrologic boundaries provide an outlet for ground water discharge. Not only is it critical to identify these features in consideration of appropriate setbacks/buffers, it is also critical to factor in their role in the overall hydrologic cycle of the landscape.

Horizons along which lateral flow would be expected include, but are not necessarily limited to: bedrock, fragipans, and zones with high clay percentage overlain by more permeable soil.

Spray irrigation design submittals should take into consideration all factors influencing the infiltrative capacity of the soil and the ability of

the soil and site to transport ground water away from the application area. It should be noted that the use of historical information from existing systems installed and operated in similar soils, with documented loading rates, landscape positions and design conditions similar to the proposed system may be applicable.

16.2 Soil Investigations

16.2.1 General

For sprayi irrigation wastewater treatment systems, moderately permeable and well-drained soils are desirable. However, the use of any soil is acceptable if it meets the following two (2) criteria:

1. The applied effluent loading rate does not exceed the applicable hydraulic loading rate in **Table 16-1**. The applicable hydraulic loading rate is determined by a detailed site evaluation in which the site is mapped utilizing soil borings and pits to determine the physical properties of soil horizons and soil map units.
2. The applied effluent maximum loading rate does not exceed 10% of the minimum NRCS saturated vertical hydraulic conductivity (K_{SAT}) for the soil series or 0.25 GPD/SF whichever is least. Note: this may have to be lowered based upon the results of the nutrient loading rate calculation per Equation 16-1.

TABLE 16-1

Hydraulic Loading Rates (GPD/SF) – For Spray Irrigation Systems

(Reference: EPA/R-00/08, February 2002, “Onsite Wastewater Treatment Systems Manual”)

TEXTURE	STRUCTURE		HYDRAULIC LOADING RATE* GPD / SF BOD ≤ 150 mg/L GPD / SF BOD ≤ 30 mg/L
	SHAPE	GRADE	
Coarse Sand, Loamy Coarse Sand	NA	NA	0.80 NA**
Sand	NA	NA	NA**
Loamy Sand, Fine Sand, Loamy Fine Sand, Very Fine Sand, Loamy Very Fine Sand	Single Grain	Structureless	0.40 1.00
Coarse Sandy Loam, Sandy Loam	Massive	Structureless	0.20 0.60
	Platy	Weak	0.20 0.50
	Angular, Blocky, Granular, Subangular	Moderate, Strong**	
		Weak	0.20 0.60
		Moderate, Strong	0.40 0.80
Loam	Massive	Structureless	0.20 0.50
	Platy	Weak, Moderate, Strong**	
	Angular, Blocky	Weak	0.40 0.60
	Granular, Subangular	Moderate, Strong	0.60 0.80
	Massive	Structureless	0.20 0.20
Silt Loam	Platy	Weak, Moderate, Strong**	
	Angular, Blocky, Granular, Subangular	Weak	0.40 0.60
		Moderate, Strong	0.60 0.80
	Massive	Structureless	
	Platy	Weak, Moderate, Strong**	
Sandy Clay Loam, Clay Loam, Silty Clay Loam	Angular, Blocky, Granular, Subangular	Weak	0.40 0.60
		Moderate, Strong	0.60 0.80
	Massive	Structureless**	
	Platy	Weak, Moderate, Strong**	
	Angular, Blocky Granular, Subangular	Weak**	
Sandy Clay Clay, Silty Clay	Granular, Subangular	Moderate, Strong**	
	Massive	Structureless	
	Platy	Weak, Moderate, Strong	
	Angular, Blocky	Weak**	
	Granular, Subangular	Moderate, Strong	0.20 0.30

* Maximum allowable is 0.25 GPD/SF

** Requires a special site investigation

Spray Irrigation will require significantly lower loading rates, or may not be allowed in soils with these characteristics

It is desirable to have a minimum depth of twenty (20) inches of undisturbed soil above a restrictive horizon (eg., rock, fragipan, high water table, etc).

16.2.2 Soil Mapping

The mapping procedure will usually begin with the property/land being generally evaluated to delineate or separate areas with suitable characteristics. This procedure will save time and money since some areas will be too shallow, too wet, too steep, etc.

Adequate ground control is mandatory for all sites. The ground control is necessary to reproduce the map if needed. All located coordinates (soil map boundaries and pit locations) must be shown on the final soils map.

Soil data collection shall be based upon one, or combination of the following:

1. Grid staking at intervals sufficient to allow the soils scientist to attest to the accuracy of the map for the intended purpose;
2. Dual frequency survey grade Global Positioning System (GPS) units.

Grid stakes and GPS data points must be locatable to within two (2) feet of distance shown.

The soil scientists are responsible for conducting a sufficient number of borings that, in their professional opinion, will allow them to certify the soils series present, identify boundaries between series, and describe each soil horizon as to color, depth to restrictive horizon, and depth to rock. Any redoximorphic features observed are to be described. Using the soil data, the soil scientist must delineate the suitable soils from the non-suitable soils. This delineation should be based upon the texture and structure of the soils to a depth of forty-eight (48) inches or restrictive horizon whichever is shallower.

After a suitable soils area is established and marked, at a minimum a soil boring to a minimum depth of forty-eight (48) inches or restrictive horizon, whichever is shallowest, shall be taken at sufficient intervals to identify and map the boundaries of the soils series present on the site. The exact number and location of borings will be determined by the soils scientist in consultation with the design engineer. Sufficient borings should be made to identify any dissimilar soils accounting for more than 10 percent of the total proposed spray irrigation area. The Soil Scientist shall excavate an adequate number of pits to determine the typical profiles and soils characteristics that are expected for all soils mapped.

The pit description must be entered onto a pedon sheet and submitted with the soils map and engineering report. The “Soil Description” must include all of the information contained on form NRCS-Soils-232G (5-86), U.S. Department of Agriculture, Natural Resources Conservation Service (see Chapter 17, Appendix D).

In their description of the pit profiles, the soil scientists must describe the soil’s structure, texture, color, and any redoximorphic features present. They should also describe root depth and presence of wormholes, macropores, etc. The depth to hard rock using an auger or a tile probe should be specified if the depth is less than forty-eight (48) inches and estimated if greater than forty-eight (48) inches. The auger borings and soil backhoe pits should be located, numbered and shown on the soil map. The soil scientist will be required to prepare and sign a detailed certification statement for each site evaluated as follows:

Soil Map Completed by:

Signature

Date

John/Jane Doe, Soils Consultant

The following statement should appear on the map:

“I, (Soils Consultant’s Name) affirm that this soil map has been prepared in accordance with accepted standards of soil science practice and the standards and methodologies established in the NRSC Soil Survey Manual and USDA *Soil Taxonomy*. No other warranties are made or implied.”

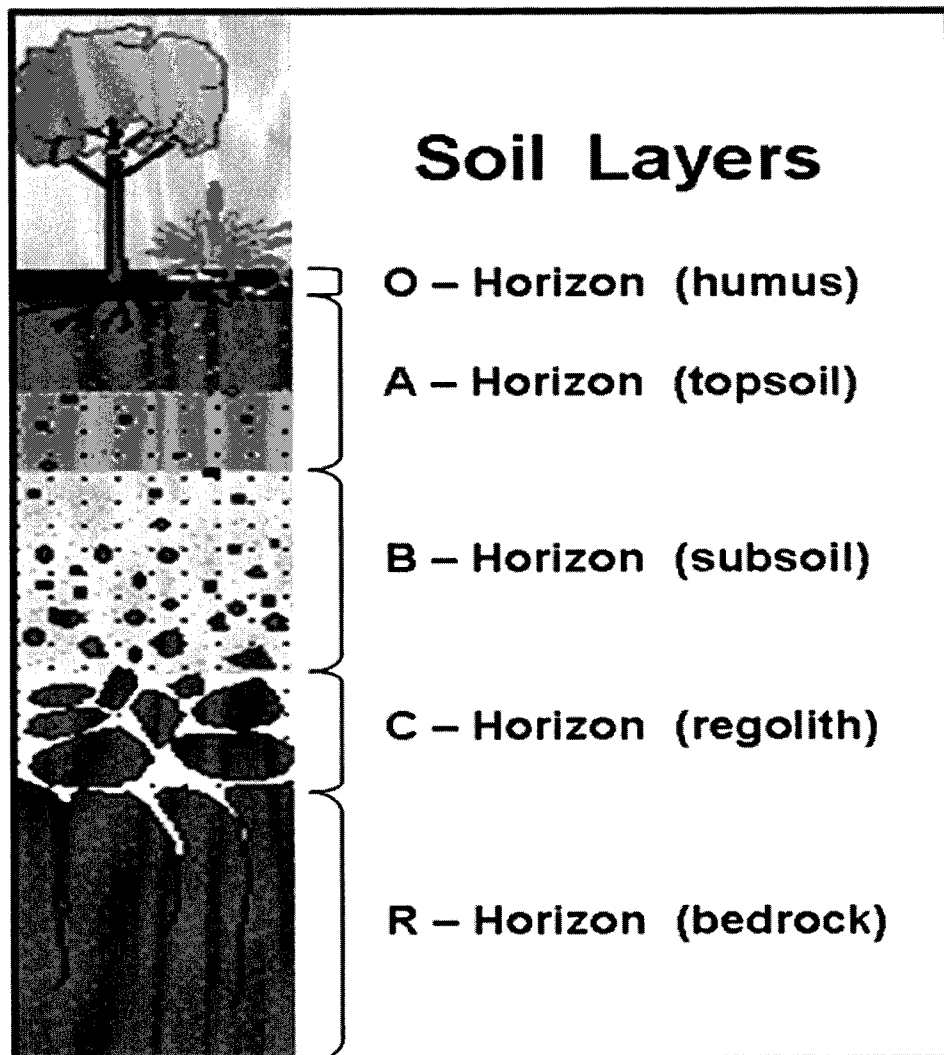
Soil profile information and pit excavation, as described in these design criteria, are additional requirements deemed necessary to properly assess an area’s suitability for spray irrigation.

16.2.3 Soil Definitions

Soil Horizons (layers): Soil is made up of distinct horizontal layers; these layers are called horizons and display vertical zones. They range from rich, organic upper layers (humus and topsoil) to underlying rocky layers (subsoil, regolith and bedrock).

Soil horizons develop due to the nature of soil formation. Soil is the product of the weathering of parent material (i.e. bedrock), accompanied by the addition of organic matter. The method for naming the soil horizons is quite simple as the **Figure 16.1** shows. In the simplest naming system, soils horizons are designated **O** (organic), **A** (topsoil), **B** (mineral soil), **C** (weathered parent material), and **R** is the unweathered rock (bedrock) layer that is beneath all the other layers. The horizons of most importance to plant growth and forest health are the **O** and **A horizons**. The **litter layer** found covering the soil is also of interest because it provides most of the organic matter found in the O and A horizons.

FIGURE 16.1



The **Litter Layer** is the topmost layer on the forest floor. It consists of leaves, needles and other non-decomposed material on the forest floor. While this is not considered part of the soil, it is interesting to measure the depth of the litter layer when sampling the soil. The depth of the litter layer can vary greatly even within a particular site. Because of this, several measurements are required to attempt to characterize litter layer depth. The litter layer can be considered part of the overall soils depth.

The **O-Horizon** primarily consists of decomposed organic matter and has a dark rich color, increased porosity, and increased aggregate structure (larger soil “clumps”). The depth of the O horizon is measured from the surface of the soil (after the litter layer has been cleared away) to the point where the darker organic color changes to a slightly lighter colored soil

that contains increased mineral particles in addition to organic matter. The transition from the O to the A horizon can also be recognized by a significant increase in the mineral soil particles. In many urban soils, the O horizon may very thin if it exists at all. The O horizon can also be considered part of the overall soils depth.

The **A-Horizon** is the **mineral** “topsoil” and consists of highly weathered **parent material** (rocks), which is somewhat lighter in color than the O horizon due to a decrease in **organic matter**. The particles in the A horizon are more granular and “crumb-like”. Seeds germinate and plant roots grow in this layer. It is made up of humus (decomposed organic matter) mixed with mineral particles. The depth of the A horizon is measured from the region of color changes from the dark O horizon to the transition to the B horizon. The transition to the B horizon can be identified by increased clay content (see below) and the absence of organic material: no root hairs, small pieces of needle, etc.

The most thorough soil study involves analysis on separate O and A horizon samples. This requires separating and storing O and A horizon samples. It also involves completing the entire soil analysis on both the O and A samples. If this is not possible, the O and A samples can be combined (or composited) and the analysis can be completed on the O and A sample together.

The **B-Horizon** is also called the **subsoil** - this layer is beneath the A horizon and above the C horizon. It contains clay and mineral deposits (like iron, aluminum oxides, and calcium carbonate) that it receives when soil solution containing dissolved minerals drips from the soil above.

The B horizon is identified by increased clay content which makes the soil hold together when moist. A simple test for clay content is to moisten a small handful of soil and attempt to smear a small portion up the forefinger. Soils high in clay will hold together and form a “ribbon”, soils with more sand and silt will be granular and fall apart. It is lighter in color and often may be reddish due to the iron content.

The **C Horizon** (layer beneath the B Horizon) consists of porous rock (broken-up bedrock, bedrock with holes). It is also called regolith or **saprolite** which means “rotten rock.” Plant roots do not penetrate into this layer; very little organic material is found in this layer.

The **R-Horizon** is the unweathered rock (bedrock) layer that is beneath all the other layers. For the purposes of drip dispersal designs, the R horizon is considered an impermeable layer.

High Intensity Soils Map. A first order survey as defined in the Soil Survey Manual, United States Department of Agriculture, October 1993. These surveys are made for various land use that requires detailed soils information. Map units are mostly soil series, phase of soil series with some complexes and miscellaneous land areas. Map scale should be one (1) inch equals one hundred (100) feet.

Extra-High Intensity Soils Map. An extra-high intensity soils map is the same as a high intensity soils map except the scale may be one (1) inch equals fifty (50) feet. These maps have more cartographic detail than a high intensity soils map. The extra-high intensity soils map is essentially a special map that shows a very high degree of soil and landscape detail and must be accompanied by specific evaluations and recommendations. Baseline mapping standards for these extra-high intensity soil maps prepared in support of drip dispersal should be in accordance with the current edition of the Soil Survey Manual, United States Department of Agriculture, October 1993. Soil profile information and pit excavation, as described in these design criteria are additional requirements deemed necessary to properly assess an area's suitability for drip dispersal. These maps should be clearly marked or labeled as "Extra High-Intensity Soils Map".

Soil map unit. A unique collection of areas that have common soil characteristics and/or miscellaneous physical and chemical features.

Most limiting horizon. A horizon in the soil (bedrock or fragipan) that either provides the greatest impediment to or completely stops, the downward movement of liquids through the soil.

16.3 Preapplication Treatment Requirements

16.3.1 General

Wastewater spray irrigation systems have a demonstrated ability to treat high strength organic wastes to low levels. However, such systems require a high degree of management with particular attention paid to organic loading rates and aeration of the soil profile between wastewater applications.

The Division of Water Pollution requires that all domestic and municipal wastewaters receive biological treatment prior to irrigation. This is necessary to:

- a. Protect the health of persons contacting the irrigated wastewater.
- b. Reduce the potential for odors in storage and irrigation.

Some industrial wastewaters may be suitable for direct land treatment by irrigation under intensive management schemes. The Division of Water Pollution Control will evaluate such systems on a case-by-case basis.

16.3.2 BOD and TSS Reduction, and Disinfection

Preapplication treatment standards for domestic and municipal wastewaters prior to storage and/or irrigation are as follows:

a. Sites Closed to Public Access

All wastewater must be treated to a level afforded by lagoons which are designed in accordance with Chapter 9.

Disinfection is generally not required for restricted and fenced access land treatment sites. The Division of Water Pollution Control may, however, require disinfection when deemed necessary.

b. Sites Open to Public Access

Sites open to public access include golf courses, cemeteries, green areas, parks, and other public or private land where public use occurs or is expected to occur. Wastewater that is spray irrigated on public access sites must not exceed a 5-day Biochemical Oxygen Demand and Total Suspended Solids of 30 mg/L, as a monthly average. Disinfection to reduce E. coli bacteria to 23 colonies/100 mL is required.

The preapplication treatment standards for wastewater that is to be applied to public access areas will be reviewed by the Division of Water Pollution Control on a case-by-case basis. More stringent preapplication treatment standards may be required as the Division of Water Pollution Control deems necessary. The Division of Water Pollution Control recommends that the engineer give preference to pretreatment systems that will provide the greatest degree of reliability.

16.3.3 Treatment and Storage Ponds

The storage pond and irrigation pump station must be hydraulically separate from the treatment cells (i.e., pumping must not affect hydraulic detention time in these cells). The Division of Water Pollution Control recommends the use of Chapter 9 of the Design Criteria for Sewage Works, as well as the United States Environmental Protection Agency's October 1983 Design Manual: Municipal Wastewater Stabilization Ponds as a reference for design of preapplication treatment ponds.

16.4 Inorganic Constituents of Treated Wastewater

Inorganic constituents of effluent from preapplication treatment should be compared with Table 16-2 to insure compatibility with land treatment site soils and cover crops.

Table 16-2

Recommended Values for Inorganic Constituents in Wastewater Surfaced Applied to Land

Potential Problem and Constituent	No Problem	Increasing Problem	Severe Problem
pH (Standard Units)	6.5 – 8.4		<5.0 or >9.0
Permeability			
Electrical Conductivity (mho/cm)	>0.50	<0.50	<2.0
Sodium Adsorption Ratio (a)	<5.0	5.0 – 9.0	>9.0
Salinity			
Electrical Conductivity (mho/cm)	<0.75	0.75 – 3.0	>3.0
Anions:			
Bicarbonate (meq/L)	<1.5	1.5 – 8.5	>8.5
(mg/L as CaCO ₃)	<150	150 – 850	>850
Chloride (meq/L)	<3.0	3.0 – 10	>10
(mg/L)	<100	100 – 300	>300
Fluoride (mg/L)	<1.8		
Cations:			
Ammonia (mg/L as N)	<5.0	5.0 – 30	>30
Sodium (meq/L)	<3.0	3.0 – 9.0	>9.0
(mg/L)	<70	70 or greater	
Trace Metals (mg/L)			
Aluminum	<10		
Arsenic	<0.2		
Beryllium	<0.2		
Boron	<0.5	0.5 – 2.0	>2.0
Cadmium	<0.02		
Chromium	<0.2		
Cobalt	<0.1		
Copper	<0.4		
Iron	<10		
Lead	<10		
Lithium	<2.5		
Manganese	<0.4		
Molybdenum	<0.02		
Nickel	<0.4		
Selenium	<0.04		
Zinc	<4.0		

$$(a) \text{ Sodium Adsorption Ratio (SAR)} = \frac{\text{Na}^{+1}}{\text{SQR} (\text{Ca}^{+2} + \text{Mg}^{+2}) / 2}$$

Where, Na+1, Ca+2, and Mg+2 in wastewater are expressed in milliequivalents per liter (meq/L).

SQR represents “Square Root of”

16.5 Protection of Irrigation Equipment

Prior to pumping to the spray field distribution system, the wastewater must be screened to remove fibers, coarse solids, oil and grease which might clog distribution pipes or spray nozzles. As a minimum, screens with a nominal diameter smaller than the smallest flow opening in the distribution system should be provided. Screening to remove solids greater than one-third ($1/3$) the diameter of the smallest sprinkler nozzle is recommended by some sprinkler manufacturers. The planned method for disposal of the screenings must be provided.

Pressurized, clean water for backwashing screens should be provided. This backwash may be manual or automated. Backwashed screenings should be captured and removed for disposal. These screenings should not be returned to the storage pond(s) or preapplication treatment system.

16.6 Determination of Design Application Rates

16.6.1 General

One of the key steps in the design of a spray irrigation system is to develop a "design application rate" in gallons per day per square foot (GPD/SF). This value is derived from either the hydraulic (water) loading rate (L_{wh}) based upon the most restrictive of (1) the NRCS hydraulic conductivity data and the texture and structure (per Table 16-1), or (2) the nutrient (nitrogen) loading rate (L_{wn}) calculations to determine design wastewater loading(s) and, thus, spray irrigation field area requirements.

16.6.2 Design Values

The most limiting horizon, of each soil series shall be identified. Any surface condition which limits the vertical or lateral drainage of the soil profile shall also be identified. Examples of such conditions are shallow bedrock, a high water table, aquitards, and extremely anisotropic soil permeability. Design considerations relative to the soils per Section 16.1.5 must be used.

Sites with seasonal high groundwater less than twenty-four (24) inches deep may require drainage improvements before they can be utilized for spray irrigation land treatment. The design hydraulic conductivity at such sites is a function of the design of the drainage system.

16.7 Determination of Design Wastewater Loading

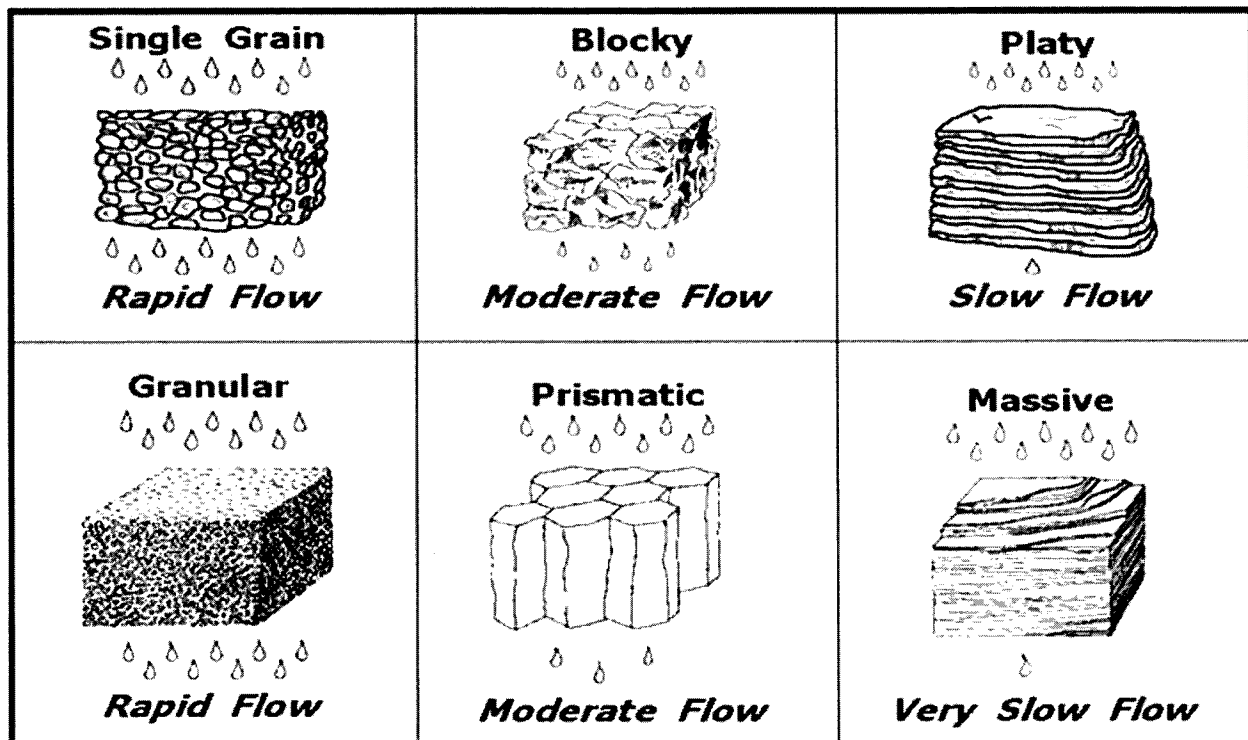
16.7.1 General

The design wastewater loading is a function of:

- Precipitation.
- Evapotranspiration.
- Design hydraulic conductivity rate.
- Nitrogen loading limitations.
- Other constituent (i.e., organic/BOD) loading limitations.
- Groundwater and drainage conditions.
- Average and peak design wastewater flows.
- Soil denitrification rates
- Rate of nitrogen uptake in site vegetation

Therefore, developing the design wastewater loading is an interactive process. The L_{wh} value is determined by a detailed site evaluation and will be dependent upon the soil characteristics as shown in Table 16-1 and pictorially represented in **Figure 16.2**. This loading is then compared to the L_{wn} loading limitations (reference Section 16.8). If the initial L_{wh} value exceeds the L_{wn} value, the design wastewater loading resulting from the nitrogen reduction evaluation described in Section 16.8 becomes the design loading rate.

FIGURE 16.2



16.8 Nitrogen Loading and Crop Selection and Management

16.8.1 General

Nitrate concentration in percolate from wastewater spray irrigation systems will be limited via a State Operation Permit (SOP) to not exceed 10 mg/L nitrate-nitrogen at the site property line. Percolate nitrate concentration is a function of nitrogen loading, cover crop, and management of vegetation and hydraulic loading. The design wastewater loading determined from using the criteria stipulated in 16.1.5 for hydraulic loading rates must be checked against nitrogen loading limitations.

16.8.2 Nitrogen Loading

In some instances, the amount of wastewater that can be applied to a site may be limited by the amount of nitrogen in the wastewater. A particular site may be limited by the nitrogen content of the wastewater during certain months of the year and limited by the infiltration rate during the remainder of the year.

16.8.3 Organic / BOD Loading

When wastewater is high strength (above 150 mg/L BOD), the organic loading rate should be limited as follows based upon the soil:

10,000 pounds of BOD per acre per year for Clays.

15, 000 pounds of BOD per acre per year for Loams.

20,000 pounds of BOD per acre per year for Sandy.

(Reference: Dr. Robert Rubin, NC State University, who cited work by Phillips and Carlile)

Equation 16-1 is used to calculate, on a monthly basis, the allowable hydraulic loading rate based on nitrogen limits:

$$\text{Lwn} = \frac{\text{Cp} (\text{Pr} - \text{PET}) + \text{U}(4.413)}{(1 - f)(\text{Cn}) - \text{Cp}} \quad (\text{Equation 16-1})$$

Where: **Lwn** = allowable monthly hydraulic loading rate based on nitrogen limits, inches/month

Cp = nitrogen concentration in the percolating wastewater, mg/L. This will usually be 10mg/L Nitrate-Nitrogen

Pr = Five-year return monthly precipitation, inches/month

PET = potential evapotranspiration, inches/month

U = nitrogen uptake by cover, lbs/acre/year pounds/acre/year (value should not exceed 100 lbs/acre/year)

Cn = Nitrate-Nitrogen concentration in applied wastewater, mg/L (after losses in preapplication treatment)

F = fraction of applied nitrogen removed by denitrification and volatilization.

The values of Lwh and Lwn are compared for each month. The lesser of the two values will be used to determine the amount of acreage needed.

NOTES:

- A “**Cn**” value of less than 23 mg/L will become a permit condition.
- The allowable vegetative uptake “**U**” of nitrogen on the drip area will be limited to an uptake rate of 100 pounds per acre per year unless trees are the vegetation.
- The “**f**” values for denitrification have been estimated based upon data supplied by the University of Tennessee and Oak Ridge National Laboratory. Denitrification rates (f) ranging from 25% in January and February to 35% in July and August are very conservative, but are defensible based upon the literature. Denitrification rates are assumed to vary linearly with the temperature and the actual rates are likely to be higher than the default values shown in Table 16-1.
- Conversion Factor - **4.413** mg-acre-inch/liter-lb. The equation and factor are from the TDHE Design Criteria for Sewage Works (April 1989). The factor comes from assuming that one pound of contaminant of concern is diluted within a volume of water equal to one acre-inch. For Example calculation see Chapter 17, Appendix 17-A. For the derivation of this factor see Chapter 17, Appendix 17-C.

Table 16-2 shows the default values for Lwn calculations. Other values may be used provided adequate rationale and documentation is presented to, and approved by the Division of Water Pollution Control.

TABLE 16-2

MONTH	Pr⁽¹⁾ Inches / Month	PET⁽²⁾ Inches / Month	N Uptake⁽³⁾ Percent / Month	f Denitrification⁽⁴⁾ Percent / Month
JAN	7.62	0.10	1%	25%
FEB	6.72	0.27	2%	25%
MAR	8.85	0.97	4%	27%
APR	6.59	2.30	8%	29%
MAY	6.13	3.59	12%	31%
JUN	5.52	4.90	15%	33%
JUL	6.85	5.44	17%	35%
AUG	4.73	5.00	15%	35%
SEP	5.54	3.79	12%	34%
OCT	4.47	1.98	8%	32%
NOV	6.11	0.82	4%	29%
DEC	7.55	0.27	2%	26%

(1) Based upon Table A-3 – 5-year return monthly precipitation

(2) Based upon Table A-2 – Potential Evapotranspiration

(3) Based upon Table A-5 – Monthly Nitrogen Uptake by Vegetation

(4) Applied Nitrogen Fraction Removed by Denitrification / Volatilization

Note: Appendix 16-B shows Equation 16-1, using the default values.

16.8.4 Cover Crop Selection and Management

Row crops may be irrigated with wastewater via spray irrigation only when not intended for direct human consumption. Livestock must not be allowed on wet fields so that severe soil compaction and reduced soil infiltration rates can be avoided. Further, wet grazing conditions can also lead to animal hoof diseases. Pasture rotation should be practiced so that wastewater spray application can be commenced immediately after livestock have been removed. In general, a pasture area should not be grazed longer than 7 days. Typical regrowth periods between grazings range from 14 to 35 days. Depending on the period of regrowth provided, one to three spray applications can be made during the regrowth period. At least 3 to 4 days drying time following an application should be allowed before livestock are returned to the pasture. Unmanaged, volunteer vegetation (i.e., weeds) is not an acceptable spray irrigation field cover. Disturbed areas in forest systems must be initially grassed and replanted for succession to forest.

Spray irrigation field cover crops require management and periodic harvesting to maintain optimum growth conditions assumed in design. Forage crops should be harvested and removed several times annually. Pine forest systems should be harvested at 20 to 25 year intervals. Hardwood forest systems should be harvested at 40 to 60 years. It is recommended that whole tree harvesting be considered to maximize nutrient removal. However, wastewater spray irrigation loadings following the harvesting of forest systems must be reduced until the hydraulic capacity of the site is restored. Spray field area to allow for harvesting and the regeneration cycle should be considered by the design engineer.

While high in nitrogen and phosphorus, domestic and municipal wastewaters are usually deficient in potassium and trace elements needed for vigorous agronomic cover crop growth. High growth rate forage crops such as Alfalfa and Coastal Bermuda will require supplemental nutrient addition to maintain nitrogen uptake rates assumed in design. Industrial wastewaters considered for irrigation should be carefully evaluated for their plant nutrient value.

16.9 Land Area Requirements

16.9.1 General

The land area to which wastewater is spray irrigated is termed a "field". The total land requirement includes not only the field area, but also land for any preapplication treatment facilities, storage reservoir(s), buffer zone, administration/maintenance structures and access roads. Field and

buffer zone requirements are addressed in this Section. Land area for storage reservoirs is discussed in Section 16.10. All other land requirements will be dictated by standard engineering practices and will not be addressed in this document.

16.9.2 Field Area Requirements

The area required for the field is determined by using the following equation:

$$A = \frac{(Q_y + V)C}{Lwd} \quad \text{Eq. 16-2}$$

where

A = field area, acres

Q_y = Flow, MG per year

V = net loss or gain in stored wastewater due to precipitation, evaporation and/or seepage at the storage reservoir, gallons per day

Lwd = design hydraulic loading rate, in/year

$$C = \frac{1,000,000 \text{ gal}}{\text{MG}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{12 \text{ in}}{\text{ft}} \times \frac{\text{acre}}{43,560 \text{ ft}^2} = 36.83$$

The first calculation of the field area must be made without considering the net gain or loss from the storage reservoir. After the storage reservoir area has been calculated, the value of V can be completed. The final field area is then recalculated to account for V. The Appendix includes the use of Equation 16-2.

16.9.3 Buffer Zone Requirements

The objectives of buffer zones around land treatment sites are to control public access, improve project aesthetics and, in case of spray irrigation, to minimize the transport of aerosols. Since development of off-site property adjacent to the treatment site may be uncontrollable, the buffer zone must be the primary means of separating the field area from off-site property. Table 16-3 gives minimum widths of buffer zones for varying site conditions:

Table 16-3
On-Site Buffer Zone Requirements

	SURFACE SPREAD	SPRINKLER SYSTEMS (Edge of Impact Zone)	
		Open Fields	Forested
Site Boundaries	100 Feet	300 Feet	150 Feet
On-Site streams, ponds and roads	50 Feet	150 Feet	75 Feet

16.10 Storage Requirements

16.10.1 General

The design of a wastewater spray irrigation land application system must take into account that wastewater application will be neither continuous nor constant. Provisions must be made for containing wastewater when conditions exist such that either wastewater cannot be applied or when the volume of wastewater to be applied exceeds the maximum application rate. The minimum storage requirement should be sixty (60) days at design flow unless engineering rationale can be presented and approved by the Division of Water Pollution Control that justifies less storage capacity.

The storage requirement may be determined and/or evaluated by either of two methods. The first method involves the use of water balance calculations and is illustrated in Appendix A. The second method involves the use of a computer program that was developed based upon an extensive NOAA study of climatic variations throughout the United States. The program entitled EPA-2 would probably be the most appropriate of the three programs available. For information on the use of the computer program, contact the National Climatic Center of NOAA at (704) 259-0448.

16.10.2 Estimation of Storage Requirements Using Water Balance Calculations

The actual wastewater that is available is compared to the actual amount that can be applied. Any excess wastewater must be stored. The actual wastewater volume must be converted to units of depth for that comparison. Equation 16-3 will be used:

$$W_p = \frac{Q_m \times C}{A_p} \quad \text{Eq. 16-3}$$

where

W_p = depth of wastewater, in inches

Q_m = volume of wastewater for each month of the year, in million gallons

$$C = \frac{1,000,000 \text{ gal}}{\text{MG}} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{\text{acre}}{43,560 \text{ ft}^2} \times \frac{12 \text{ in}}{\text{ft}} = 36.83$$

A_p = field area, in acres

The months in which storage is required are cumulated to determine the maximum amount of total storage needed. The use of the method is illustrated in Appendix A.

The maximum storage amount in inches, over the field area, is converted to a volume, in cubic feet. A suitable depth is chosen and a storage basin surface area is calculated.

This storage basin will be affected by three factors: precipitation, evaporation and seepage. These three factors are determined and the result is V , which is then introduced back into equation 16-2. A new, final field area is calculated and a corresponding new storage volume is determined.

In Tennessee, the maximum seepage is 1/4 inch per day. This amount can be used unless the storage basin will be constructed so that a lesser seepage rate will result. In some cases, where an impervious liner will be constructed, the seepage rate will be zero.

16.11 Distribution System

16.11.1 General

The design of the distribution system is a critical aspect of the land application. The field area and the storage volume were derived with the assumption that wastewater would be evenly distributed. For high strength wastes or wastes with high suspended/settleable solids, sprinkler applications are preformed. Sprinklers will distribute these wastes more evenly over the treatment area whereas surface application may result in accumulation of solids and odors near the application point.

16.11.2 Surface Spreading

With surface spreading, wastewater is applied to the ground surface, usually by perforated pipe or by an irrigation-type ditch, and flows uniformly over the field by gravity. The uniform flow is critically dependent upon a constant slope of the field, both horizontal and perpendicular to the direction of flow. Several other factors are of importance:

- a. Uniform distribution cannot be achieved on highly permeable soils. The wastewater will tend to percolate into the soil that is nearest to the point of application.
- b. A relatively large amount of wastewater must be applied each time so that wastewater will reach all portions of the field. The dosing must account for the fact that the field area nearest the point of application will be wetted for a longer period of time and, thus, will percolate more wastewater.
- c. Erosion and/or runoff may be a problem. Since a surface discharge will not be allowed to occur, a return system may be necessary.

16.11.3 Sprinkler Spreading

Sprinkler systems can be classified into one of three general categories: (1) solid set, (2) portable and (3) continuously moving. The following factors should be considered during design:

- a. The hydraulic conditions within the distribution system must be given a thorough review. Head losses through pipes, bends, nozzles, etc., must be balanced so that the wastewater is uniformly applied to the field.
- b. Design must consider the effects of cold weather. Nozzles, risers, supply pipes, etc., must be designed to prevent wastewater from freezing in the various parts.
- c. Wind can distort the spray pattern. Also, aerosols may be carried off the field area. A properly designed buffer zone should alleviate most of the aerosol problems. Also, the O&M manual can include a provision which would prevent spraying when the wind velocity is high enough to carry wastewater off the field area.

- d. Crop selection is important. The higher humidity level may lead to an increase in crop disease.
- e. Higher slopes can be used than in surface spreading. Also, slopes do not need to be constant. Further, the type of crop is nearly unlimited. Forests can be irrigated with solid set sprinklers. Forage crops can be irrigated with any of the three basic types of systems.
- f. The system layout must take into consideration the method that will be used for harvesting the crop.

16.12 Spray Irrigation of Wastewater from Gray Water Facilities

16.12.1 General

This Section provides criteria for facilities that produce a "gray water" wastewater. These facilities include coin-operated laundries, car washes and swimming pool backwash filters. Wastewater disposal requirements are not as complex as are those for domestic wastewater. An engineering report which provides information on the design of the facilities must be submitted to the Division of Water Pollution Control.

16.12.2 Site Location

- 16.12.2.1 The Division of Water Pollution Control must inspect and approve the proposed site prior to any construction being undertaken.
- 16.12.2.2 The site must be chosen such that the operation of the system will not affect surrounding property owners. No surface runoff or stream discharge will be allowed.

16.12.3 Design Flow

Since these are service enterprises, the amount of wastewater that is generated is directly related to the desire of people to use the facilities. Thus, an estimate of the number of potential users (and frequency) is extremely important. Various factors must be taken into consideration:

- a. A rural setting would tend to have a shorter daily usage period than would an urban location.

- b. An area that is predominately single-family houses would tend to have a lesser usage rate for laundries and car washes than would an area with apartment complexes.
- c. The amount of water that washing machines use will vary among manufacturers and models. The Division recommends the use of water-saving machines.

The design engineer should use 250 gpd/washer for laundries and 700 gpd/bay for car washes unless more reliable data is available.

16.12.4 Pretreatment

16.12.4.1 General

Facilities that produce gray water have different pretreatment requirements, designed not only to the type of facility but also to the specific establishment.

16.12.4.2 Laundries

- a. All laundry wastewater (does not include sanitary wastes) shall pass through a series of lint screens. A series will consist of five screens, starting with a screen with 1-inch mesh and ending with a screen that is basically equivalent to a window screen.
- b. Since some detergents produce a wastewater with a pH in the range of 11.0 - 11.5, some type of pH adjustment may be necessary. This may occur as a retrofit if the vegetation in the spray plots is being stressed by the high pH.
- c. Disinfection will generally not be required unless the operation of the facilities will result in a potential hazard to the public. The need for disinfection will be determined by the Division of Water Pollution Control on a case-by-case basis.

16.12.4.3 Car Washes

- a. All car wash wastewater shall pass through a grit removal unit. The flow-through velocity shall be less than 0.5 feet per second. The grit removal unit shall be constructed to facilitate the removal of grit.

- b. The use of detergents with a neutral (or nearly neutral) pH is recommended. The use of high-pH detergents may require neutralization if the vegetation is being stressed by the high pH.

16.12.4.4 Swimming Pools

- a. A holding tank/pond shall be provided to receive the backwash water from the swimming pool filters. The solids shall be allowed to settle to the bottom before the supernatant is removed for disposition on the spray plots.
- b. Dechlorination may be required if the vegetation on the plots is being stressed by the chlorine in the water.
- c. If the entire pool volume is to be emptied, by using the spray plots, the rate shall be controlled so as to not exceed the application rate that is specified in Section 16.7.

16.12.5 Field Requirements

- 16.12.5.1 The maximum wastewater that can be sprayed on a site is based either on the nitrogen content of the wastewater or an amount equal to 10% of the infiltration rate of the most restrictive layer of soil which shall be determined by the design engineer with input from a qualified soil scientist.
- 16.12.5.2 The application of wastewater shall alternate between at least two separate plots. Each plot shall not receive wastewater for more than three consecutive days and must have at least three days rest between applications. Reserve land area of equivalent capacity must be available for all gray water systems.
- 16.12.5.3 Ground slopes shall not exceed 30%. Extra precautions must be taken on steep slopes (15-30%) to prevent runoff and erosion.
- 16.12.5.4 The field shall be covered with a good lawn or pasture grass unless an existing forested area is chosen. The ground cover should be a sturdy perennial that will resist erosion and washout. Forested areas should be chosen so that installation of sprinkler equipment will not damage the root systems of the trees and will not produce runoff due to the usual lack of grass in forested areas.

16.12.6 Application Equipment

- 16.12.6.1 Sprinklers shall be of a type and number such that the wastewater will be evenly distributed over the entirety of a plot. Information on sprinklers shall be included in the engineering report. In forest plots, sprinklers shall be on risers which shall be tall enough to allow the wastewater to be sprayed above the undergrowth. Sprinklers shall be of the type that are not susceptible to clogging.
- 16.12.6.2 All piping (excluding risers) shall be buried to a depth that will prevent freezing in the lines. An exception to this burial requirement can be made in the case where piping will be laid in forested areas. Burial in this case may be difficult, expensive and may kill some trees. All risers shall be designed such that wastewater will drain from them when wastewater is not being pumped. This can be accomplished by either draining all lines back into the pump sump or by placing a gravel drain pit at the base of each riser. Each riser would necessarily be equipped with a weep hole. Particular attention must be given during the design so that the entire subsurface piping does not drain into these pits.
- 16.12.6.3 The engineering report must contain hydraulic calculations that show that each nozzle distributes an equivalent amount of wastewater. Differences in elevation and decreasing pipe sizes will be factors which need to be addressed.
- 16.12.6.4 The piping must be of a type that will withstand a pressure equal to or greater than 1-1/2 times the highest pressure point in the system. The risers should be of a type of material such that they can remain erect without support. The pipe joints should comply with the appropriate ASTM requirements. Adequate thrust blocks shall be installed as necessary.
- 16.12.6.5 A sump shall be provided into which the wastewater will flow for pumping to the spray plots. The pump can be either a submersible type, located in the sump, or a dry-well type, located immediately adjacent to the sump in a dry-well. The pump shall be capable of pumping the maximum flow that can be expected to enter the sump in any 10-minute period. The pump shall be operated by some type of float mechanism. The float mechanism shall activate the pump when the water level reaches 2/3 of the depth of the sump and should de-activate the pump before

the water level drops to the point to where air can enter the intake.

If the distribution system is designed to drain back into the sump, the sump shall be enlarged to account for that volume.

If desired, the sump for laundries can also contain the lint screens. The screens shall, in any case, be constructed so that they cannot be bypassed. They shall be built so that they can be easily cleaned. A container shall be provided for disposal of the lint which is removed from the screens.

- 16.12.6.6 The pipe from the facility to the sump shall be large enough to handle the peak instantaneous flow that could be realistically generated by the facility. Flow quantities, head loss calculations, etc., shall be included in the engineering report.

16.12.7 Operation of System

- 16.12.7.1 The operator shall insure that wastewater is applied to alternate plots on a regular basis.
- 16.12.7.2 Monthly operating reports shall be submitted to the appropriate field office of the Division of Water Pollution Control. The parameters to be reported shall be delineated by field office personnel but should include, as a minimum, dates of spray plot alternation.
- 16.12.7.3 The owner of the system shall apply for and receive an operating permit from the Division of Water Pollution Control prior to initiation of operation of the system.

16.12.7.4

The system operator shall inspect and maintain the pump and sprinklers in accordance with manufacturer's recommendations. An operations manual shall be located at the facility for ready reference.

- 16.12.7.5 The operator shall inspect the wastewater facilities on a regular basis. The inspection shall include the spray plots to determine whether or not runoff and/or erosion are or have occurred, the spray patterns of the sprinklers, the

physical condition of the system (looking for damage due to adverse pH conditions, etc.)

- 16.12.7.6 The spray plots shall be mowed on a regular basis to enhance evapotranspiration. Grass height shall not exceed 6-inches.
- 16.12.7.7 The lint screen at laundries shall be cleaned on a schedule that is frequent enough to prevent upstream problems due to head loss through the screens. Disposition of the lint shall be in accordance with applicable requirements.
- 16.12.7.8 The grit traps at car washes shall be cleaned at a frequency that is sufficient to keep the trap in its designed operating condition.
- 16.12.7.9 If the car wash is equipped with an automatic wax cycle, the operator shall be especially attentive to the possibility of wax build-up on the sump, pump and all downstream piping.
- 16.12.7.10 The operator shall insure that the car wash facility is not used as a sanitary dumping station for motor homes or for washing trucks/trailers that are used for hauling livestock. If necessary, the facility shall be posted with signs which clearly indicate this prohibition.
- 16.12.7.11 The sludge holding tank/pond at a swimming pool facility shall be cleaned at a frequency that is sufficient to prevent solids from being carried over into the pump sump. Cleaning shall be performed in a manner that will minimize re-suspending the solids and allowing them to enter the pump sump.

16.13 Plan of Operation and Management

A Plan of Operation and Management (POM) is required before an Operation Permit (SOP) can be issued. The Plan is written by the owner or the owner's engineer during construction of the slow rate land treatment system. Once accepted by the Division, the Plan becomes the operating and monitoring manual for the facility and is incorporated by reference into the Permit. This manual must be kept at the facility site and must be available for inspection by personnel from the Tennessee Department of Health and Environment.

This POM should include, but not be limited to, the following information:

16.13.1 Introduction

a. System Description:

1. A narrative description and process design summary for the land treatment facility including the design wastewater flow, design wastewater characteristics, preapplication treatment system and spray fields.
2. A map of the land treatment facility showing the preapplication treatment system, storage pond(s), spray fields, buffer zones, roads, streams, drainage system discharges, monitoring wells, etc.
3. A map of force mains and pump stations tributary to the land treatment facility. Indicate their size and capacity.
4. A schematic and plan of the preapplication treatment system and storage pond(s) identifying all pumps, valves and process control points.
5. A schematic and plan of the irrigation distribution system identifying all pumps, valves, gauges, sprinklers, etc.

b. Discuss the design life of the facility and factors that may shorten its useful life. Include procedures or precautions which will compensate for these limitations.

c. A copy of facility's Tennessee Operation Permit.

16.13.2 Management and Staffing

a. Discuss management's responsibilities and duties.

b. Discuss staffing requirements and duties:

1. Describe the various job titles, number of positions, qualifications, experience, training, etc.
2. Define the work hours, duties and responsibilities of each staff member.

16.13.3 Facility Operation and Management

a. Preapplication Treatment System:

1. Describe how the system is to be operated.
2. Discuss process control.
3. Discuss maintenance schedules and procedures

b. Irrigation System Management:

1. Wastewater Application. Discuss how the following will be monitored and controlled. Include rate and loading limits.
 - (a) Wastewater loading rate (inches/week)
 - (b) Wastewater application rate (inches/hour)
 - (c) Spray field application cycles
 - (d) Organic, nitrogen and phosphorus loadings (lbs/acre per month, etc)
2. Discuss how the system is to be operated and maintained.
 - (a) Storage pond(s)
 - (b) Irrigation pump station(s)
 - (c) Spray field force main(s) and laterals
3. Discuss start-up and shut-down procedures.
4. Discuss system maintenance.
 - (a) Equipment inspection schedules
 - (b) Equipment maintenance schedules
5. Discuss operating procedures for adverse conditions.
 - (a) Wet weather

- (b) Freezing weather
 - (c) Saturated Soil
 - (d) Excessive winds
 - (e) Electrical and mechanical malfunctions
- 6. Provide troubleshooting procedures for common or expected problems.
- 7. Discuss the operation and maintenance of back-up, stand-by and support equipment.
- c. Vegetation Management:
 - 1. Discuss how the selected cover crop is to be established, monitored and maintained.
 - 2. Discuss cover crop cultivation procedures, harvesting schedules and uses.
 - 3. Discuss buffer zone vegetative cover and its maintenance.
- d. Drainage System (if applicable):
 - 1. Discuss operation and maintenance of surface drainage and runoff control structures.
 - 2. Discuss operation and maintenance of subsurface drainage systems.

16.13.4 Monitoring Program

- a. Discuss sampling procedures, frequency, location and parameters for:
 - 1. Preapplication treatment system.
 - 2. Irrigation System:
 - (a) Storage pond(s)
 - (b) Groundwater monitoring wells

- (c) Drainage system discharges (if applicable)
 - (d) Surface water (if applicable)
- b. Discuss soil sampling and testing:
- c. Discuss ambient conditions monitoring:
 - 1. Rainfall
 - 2. Wind speed
 - 3. Soil moisture
- d. Discuss the interpretation of monitoring results and facility operation:
 - 1. Preapplication treatment system.
 - 2. Spray fields.
 - 3. Soils.

16.13.5 Records and Reports

- a. Discuss maintenance records:
 - 1. Preventive.
 - 2. Corrective.
- b. Monitoring reports and/or records should include:
 - 1. Preapplication treatment system and storage pond(s).
 - (a) Influent flow
 - (b) Influent and effluent wastewater characteristics
 - 2. Irrigation System.
 - (a) Wastewater volume applied to spray fields.
 - (b) Spray field scheduling.

(c) Loading rates.

3. Groundwater Depth.
4. Drainage system discharge parameters (if applicable).
5. Surface water parameters (if applicable).
6. Soils data.
7. Rainfall and climatic data.